Photo: Mike Weimer, U.S. Fish & Wildlife Service

Human Health

Section 8

Section 8: Human Health

8.1 Introduction

There is concern about the effects that Great Lakes' contaminants and, in particular persistent, bioaccumulative toxic chemicals, may have on human health. The 1987 Protocol to the Great Lakes Water Quality Agreement of 1978 (GLWQA) states that Lakewide Management Plans (LaMPs) for open lake waters shall include: "A definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combination with another substance, including their contribution to the impairment of beneficial uses." Critical pollutants are those persistent bioaccumulative toxic chemicals that have caused, or are likely to cause, impairments of the beneficial uses of each Great Lake. Three of these beneficial uses (fish consumption, drinking water consumption and recreational water use) are directly related to human health. The goal of this Lake Erie LaMP section is to fulfill the human health requirements of the GLWQA, including:

- Define the threat to human health and describe the potential adverse human health effects arising from exposure to critical pollutants and other contaminants (including microbial contaminants) found in the Lake Erie basin;
- Address current and emerging human health issues of relevance to the LaMP but not currently addressed in the other components of the LaMP; and
- Identify implementation strategies currently being undertaken to protect human health and suggest additional implementation strategies that would enhance the protection of human health.

In defining the threat to human health from exposure to the Lake Erie LaMP critical pollutants (PCBs and mercury), and the other Lake Erie LaMP pollutants of concern (Table 5.2), this assessment applies a weight of evidence approach that uses the overall evidence from wildlife studies, experimental animal studies, and human studies in combination. In addition to examining the chemical pollutants of concern to human health for Lake Erie, this section also examines microbial pollutants in recreational and drinking water.

The World Health Organization defines human health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization 1984). Therefore, when assessing human health, all aspects of well-being need to be considered, including physical, social, emotional, spiritual and environmental impacts on health. Human health is influenced by a range of factors, such as the physical environment (including environmental contaminants), heredity, lifestyle (smoking, drinking, diet and exercise), occupation, the social and economic environment the person lives in, or combinations of these factors. Exposure to environmental contaminants is one among many factors that contribute to the state of our health (Health Canada 1997).

Consideration of human health in the Lake Erie basin must also take into account the diversity of the Lake Erie basin population, which includes a range of ethnic and socioeconomic groups. Certain subpopulations, such as high fish consumers, may have higher exposures to persistent toxic chemicals than the general population. In addition, some subpopulations, such as the elderly, immunologically compromised, women of child-bearing age, the fetus, nursing infants, and children may be more susceptible to the effects of persistent bioaccumulative toxic chemicals (Johnson et al. 1998; Health Canada 1998d). Therefore, the discussion of health issues in this section looks at the health of the general population as well as subpopulations at increased risk of exposure and health effects.

8.2 Great Lakes Human Health Network

In an effort to improve Great Lakes-related human health communication across the basin and to address health issues common to all the Great Lakes, the Great Lakes Human Health Network (Network) was established. The Network was formed in December 2002 under the guidance of the Binational Executive Committee (BEC) to create a forum to identify and discuss human health issues directly related to Great Lakes water quality.

The Network is a voluntary partnership of representatives from both U.S. and Canadian government agencies, and also includes the involvement of public health experts. The Network was specifically designed to support the LaMP and Remedial Action Plan (RAP) processes and to facilitate addressing human health issues that may go beyond the more typical issues of fish and wildlife consumption advisories, beach postings and clean drinking water.

Currently, the Network has representatives from six federal government agencies, five tribal government agencies, eleven state and provincial government agencies, and one county government agency. Network membership continues to build. To learn more about the Network, go to www.epa.gov/glnpo/health.html.

8.3 Pathways of Exposure and Human Health

The three major routes through which chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure). The major pathway is by ingestion, particularly of food. For the LaMP these largely relate to the following beneficial use impairments: fish and wildlife consumption advisories, restrictions on drinking water, and beach postings. Awareness of the underlying causes of these restrictions (e.g., chemical and microbial contaminants) and the associated health consequences will allow public health agencies to develop societal responses protective of public health. Desired outcomes for human health and the exposure pathways they relate to are identified in Table 8.1.

The scope of the Lake Erie LaMP includes pathways of exposure through the water. Therefore, air pollution is not discussed. Nonetheless, air pollution as it relates to the air we breathe is a key health issue for the Lake Erie basin, and programs and initiatives are in place in both the U.S. and Canada that address this issue. For the United States, the Clean Air Act, implemented by the U.S. EPA and state agencies, is primarily responsible for ensuring the quality of ambient air by regulating point and mobile source emissions to the environment (for more information refer to www.epa.gov/oar/oarhome.html). The Occupational Safety and Health Administration implements the Occupational Safety and Health Act that protects health in the workplace - including health related to air quality (for more information refer to www.osha.gov).

In Canada, Health Canada conducts air pollution health effects research, risk assessments and exposure guidelines creation through the Air Pollution Health Effects Research Program in its Environmental Health Directorate (www.hc-sc.gc.ca/hecs-sesc/hecs/index.htm). The Province of Ontario also has programs targeted at the protection of humans from exposure to air pollution.

The critical pollutants and chemical pollutants of concern in Lake Erie include organochlorines and metals that are known to cause adverse health effects in animals and humans. These chemicals do not break down easily, persist in the environment and bioaccumulate in aquatic biota, animal and human tissue - thus they are called *persistent bioaccumulative toxic* chemicals (PBTs). Organochlorines tend to accumulate in fat (such as adipose tissue and breast milk), and metals tend to accumulate in organs, muscle and flesh. Food is the primary route of human exposure to these PBT chemicals, and consumption

Table 8.1: Human Health-Related Desired Outcomes, and Pathways of Exposure

Desired Outcomes	Pathway of Exposure
Fishable - We can all eat any fish	Ingestion of food (fish)
Drinkable - Treated drinking water is safe for human consumption; We can all drink the water	Ingestion of water
Swimmable - All beaches are open and available for public swimming; We can all swim in the water with no health impacts	Incidental ingestion of water, dermal contact, inhalation of water spray from splashing, etc.

of Great Lakes fish is the most important source of exposure originating directly from the lakes. Sources from air, soil/dust, and water constitute a minor route of exposure (Health Canada 1998e; Johnson et al. 1998).

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin. For example, lead concentrations in blood and organochlorine contaminants in breast milk have declined. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Therefore, public health advisories and other guidelines should be followed to minimize contaminant exposures. Most of the health effects studies for Great Lakes PBT chemicals have focused on fish consumption.

Photo: Upper Thames River Conservation Authority

8.3.1 Drinking Water

Access to clean drinking water is essential to good health. The waters of Lake Erie and surrounding areas are a primary source of drinking water for people who live in the Lake Erie basin. The average adult drinks about 1.5 liters of water a day, so health effects could be serious if high levels of some contaminants are present (Health Canada 1993, 1997).

A variety of contaminants can adversely affect drinking water, including: microorganisms (e.g. bacteria, viruses and protozoa, such as *cryptosporidium*); chemical contaminants (both naturally occurring, synthetic and anthropogenic); and radiological contaminants, including naturally occurring inorganic and radioactive materials (IJC 1996; Health Canada 1997; Lake Erie LaMP 1999; OME 1999). Some contaminants in raw water supplies, such as aluminum, arsenic, copper and lead, can be both naturally occurring and result from human activities. Other contaminants, such as household chemicals, industrial products, fertilizers (including nitrates), human and animal wastes, and pesticides may also end up in raw water supplies (U.S. EPA 1999a; Health Canada 1998b).

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. Some individuals or groups, particularly children and the elderly, may be more sensitive to contaminants in drinking water than the average person (Health Canada 1993). The illnesses associated with contaminated drinking water are mainly of a gastrointestinal nature, including diarrhea, nausea, stomach cramps, and other symptoms, although some pathogens are capable of causing severe and life-threatening illness (Health Canada 1995a). Microbial contamination of municipal water supplies has been largely eliminated through treatment of drinking water prior to distribution to the consumer (contaminants are removed and disinfectants such as chlorine are added to prevent waterborne disease). As a result of this treatment, diseases such as typhoid and cholera have been virtually eliminated. Although other disinfectants are available, chlorine still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation, filtration), chlorine is effective against virtually all infective agents (U.S. EPA and Government of Canada 1995; Health Canada 1993, 1997 and 1998b).

Drinking water utilities today find themselves facing new responsibilities. While their mission has always been to deliver a dependable and safe supply of water to their customers, the challenges inherent in achieving that mission have expanded to include security and counter-terrorism. In the Public Health Security and Bioterrorism and Response Act of 2002, the U.S. Congress recognized the need for drinking water systems to undertake a more comprehensive view of water safety and security. The Act amends the U.S. Safe Drinking Water Act and specifies actions community water systems and the U.S. EPA must take to improve the security of the nation's drinking water infrastructure. For more information, go to www.epa.gov/safewater/security/index.html.

In 2002 the Province of Ontario passed the Safe Drinking Water Act. This Act expands on existing policy and practice and introduces new features to protect drinking water in Ontario. Its purpose is to protect human health through the control and regulation of drinking water systems and drinking water testing. For more information refer to www.ene.gov.on.ca/envision/water/sdwa/.

8.3.2 Recreational Water

The Great Lakes are an important resource for recreational activities that involve full body contact with water, such as swimming, water-skiing, sailboarding and wading. Apart from the risks of accidental injuries, the major human health concern for recreational waters is microbial contamination by bacteria, viruses, and protozoa (Health Canada 1998; World Health Organization 1998).

Many sources or conditions can contribute to microbiological contamination, including combined sewer overflows after heavy rains (Whitman et al. 1995). On-shore winds can stir up sediment or transport bacteria in from contaminated areas. Animal/pet waste may be deposited on beaches or washed into storm sewers. Agricultural runoff, such as manure, is another source. Storm water runoff in rural and wilderness area watersheds can increase densities of fecal streptococci and fecal coliforms as well (Whitman et al. 1995). Other contaminant sources include infected bathers/swimmers; direct discharges of sewage from recreational vessels; and malfunctioning private systems (e.g. cottages, resorts) (Health Canada 1998; Whitman et al. 1995; World Health Organization 1998).

The Great Lakes Water Quality Agreement calls for recreational waters to be substantially free from bacteria, fungi, and viruses. Human exposure to microorganisms occurs primarily through ingestion of water, and can also occur via the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Gastrointestinal disorders, respiratory illness and minor skin, eye, ear, nose, and throat infections have been associated with microbial contamination of recreational waters (Health Canada 1998a; Whitman et al. 1995; World Health Organization 1998). The risk of illness is dependent upon the degree of water pollution, the individual's level of exposure, immunization status (e.g., polio), and the general health of the individual. For this reason, the protection of public health is directed at controlling microbial pollutants in recreational waters. See Table 8.2 for the swimming associated illnesses.

Table 8.2: Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	Disease
Bacteria	
Campylobacter jejuni	Gastroenteritis
E. coli	Gastroenteritis
Salmonella typhi	Typhoid fever
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia (generalized infections in which organisms multiply in the bloodstream)
Shigella dysenteriae and other species	Bacterial dysentery
Vibrio cholera	Cholera
Yersinia spp.	Acute gastroenteritis (including diarrhea, abdominal pain)
Viruses	
Adenovirus	Respiratory and gastrointestinal infections
Coxsackievirus (some strains)	Various, including severe respiratory diseases, fevers, rashes, paralysis, aseptic meningitis, myocarditis
Echovirus	Various, similar to coxsackievirus (evidence is not definitive except in experimental animals)
Hepatitis	Infectious hepatitis (liver malfunction); also may affect kidneys and spleen
Norwalk virus	Gastroenteritis
Poliovirus	Poliomyelitis
Reovirus	Respiratory infections, gastroenteritis
Rotavirus	Gastroenteritis
Protozoa	
Balantidium coli	Dysentery, intestinal ulcers
Cryptosporidium	Gastroenteritis
Entamoeba histolytica	Amoebic dysentery, infections of other organs
Giardia lambia	Diarrhea (intestinal parasite)
Isospora belli and *Isospora hominus*	Intestinal parasites, gastrointestinal infection
Toxoplasma gondii	Toxoplasmosis

(NRDC, 2003)

Studies have shown that swimmers and people engaging in other recreational water sports have a higher incidence of symptomatic illnesses such as gastroenteritis, otitis, skin infection, conjunctivitis, and acute febrile respiratory illness following activities in polluted recreational waters (Dewailly 1986; World Health Organization 1998). Although current studies are not sufficiently validated to allow calculation of risk levels (Health Canada 1992), there is some evidence that swimmers/bathers tend to be at a significantly elevated risk of contracting certain illnesses (most frequently upper respiratory or gastrointestinal illness) when compared with people who do not enter polluted water (Dufour 1984; Seyfried 1985a, b; U.S. EPA 1986; World Health Organization 1998). In addition, children, the elderly, and people with weakened immune systems are more likely to develop illnesses or infections after swimming in polluted water (Health Canada 1998). Despite these studies, there are challenges in establishing a clear relationship between recreational water exposure and disease outcomes. Less severe symptoms resulting from exposure to microorganisms are not usually reported, which makes statistics on cases related to recreational water exposure difficult to determine. In addition, the implicated body of water is not often tested for the responsible organism and when it is tested, the organism is not usually recovered from the sample. With the exception of gastrointestinal illness, a direct relationship between bacteriological quality of the water and symptoms has not been shown — a causal relationship exists between gastrointestinal symptoms and recreational water quality as measured by indicator-bacteria concentrations (World Health Organization 1998). Therefore, research efforts are focused on epidemiological studies to establish the relationships between diseases and the presence of microorganisms in the water (Health Canada 1997; Health Canada 1998; U.S. EPA 1999).

The primary cause for beach closings and advisories is the high level of indicator bacteria in recreational waters. Elevated bacterial levels can be the result of several different problems ranging from flooding to point source releases. The best way to protect swimmers is to eliminate the need for beach closings in the first place. Conserving water, keeping septic systems maintained, and properly disposing of boat sewage and animal waste helps to reduce beach water contamination. Sewage treatment plants need to be improved and direct discharges of raw sewage into the water from combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) need to be eliminated.

Chemical contaminants such as PAHs and PCBs have been identified as a possible concern for dermal (skin) exposure in recreational waters. Dermal exposure may occur when people come into contact with contaminated sediment or contaminated suspended sediment particulates in the water. PAHs and PCBs adsorbed to these particulates would adhere to the skin. There is little information available regarding chemical contaminants with the potential to cause effects such as skin rashes, or how much of a chemical might be absorbed through the skin, with the potential to cause systemic effects, such as cancer (Hussain et al. 1998; Lake Erie LaMP 1999).

Photo: Upper Thames River Conservation Authority

8.3.3 Fish Contaminants

Exposure assessments from all sources (air, water, food and soil) were completed for the Canadian Great Lakes basin general population for 11 PBT chemicals, including PCBs and mercury. The total estimated daily intake averaged over a lifetime was well below the Tolerable Daily Intake (TDI) established by Health Canada (Health Canada, 1998c). Consequently, the approach by various agencies has been to examine groups at higher risk of exposure to PBT chemicals from Great Lakes sources, such as high consumers of sport fish.

Fish are low in fat, high in protein, and may have substantial health benefits when eaten in place of high-fat foods. The levels of the chemicals in fish from the Lake Erie basin are generally low and do not cause acute illness. However, chemicals such as mercury and PCBs enter the aquatic environment and build up in the food chain. Continued low-level exposure to these chemicals may result in adverse human health effects. People need to be aware of the presence of contaminants in sport fish and, in some cases, take action to reduce exposure to chemicals while still enjoying the benefits of catching and eating fish.

Contaminants usually persist in surface waters at very low concentrations. They can bioaccumulate in aquatic organisms and become concentrated at levels that are much higher than in the water column. This is especially true for substances that do not break down readily in the environment, such as the Lake Erie LaMP critical pollutants PCBs and mercury. As contaminants bioaccumulate in aquatic organisms, this effect biomagnifies with each level of the food chain. As a result of this effect, the concentration of contaminants in the tissues of top predators, such as lake trout and large salmon, can be millions of times higher than the concentration in the water. Figure 8.1 illustrates an example of the changes in PCB concentration (in parts per million, ppm) at each level of a Great Lakes aquatic food chain. The highest levels are reached in the eggs of fish-eating birds such as herring gulls.

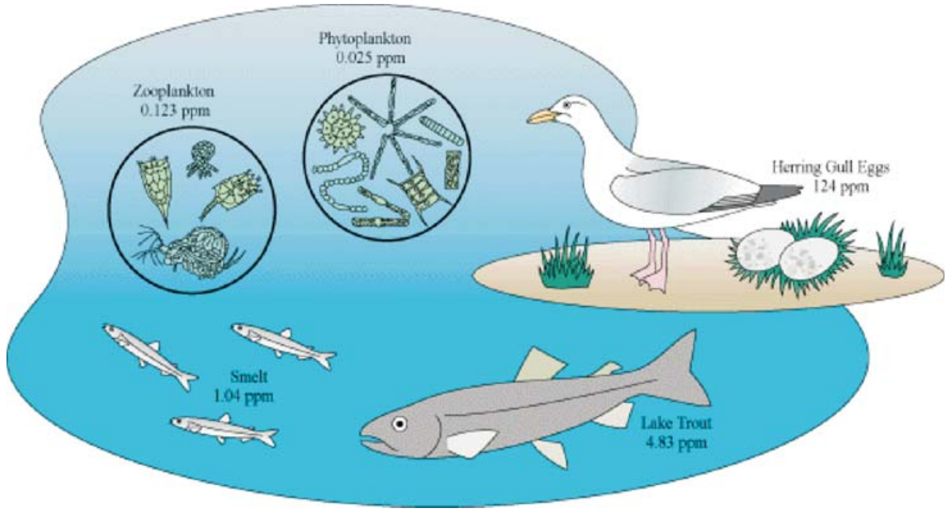

Figure 8.1: Persistent organic chemicals such as PCBs bioaccumulate and biomagnify

8.4 Evidence for Potential Health Effects - Weight of Evidence Approach to Linking Environmental Exposure

The following three subsections describe selected studies that have reported associations between PBT chemical exposures and effects in wildlife, laboratory animals and human populations. Because of the ethical issue of exposing humans to toxic substances and factors such as a small sample size and presence of multiple chemicals, human studies are often limited in their ability to establish a causal relationship between exposure to chemicals and potential adverse human health effects. Human studies looking at causal relationships between human exposure to environmental contaminants and adverse health outcomes are limited and the results uncertain. Therefore, a weight of evidence approach is used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered in combination. It utilizes the available information from wildlife and controlled animal experiments to supplement the results of human studies toward assessing the risks to human health from exposure to PBT chemicals. The use of wildlife data assumes that animals can act as sentinels for adverse effects observed in humans (Johnson and Jones 1992).

8.4.1 Wildlife Populations

Research over the past 25 years has shown that a variety of persistent, bioaccumulative contaminants in the Great Lakes food chain are toxic to wildlife (Health Canada 1997). Reproductive impairments have been described in avian, fish, and mammalian populations in the Great Lakes. For example, egg loss due to eggshell thinning has been observed in predatory birds, such as the bald eagle, within the Great Lakes (Menzer and Nelson 1980). After feeding on Great Lakes fish for two or more years, immigrant birds (eagles) were shown to have a decline in reproductive success (Colburn et al. 1993). Developmental effects in the form of congenital deformities (e.g. crossed mandibles, club feet) have also been reported in the avian population within the Great Lakes basin (Stone 1992).

Effects on the endocrine system and tumor formations have been detected in fish populations. Researchers have reported enlarged thyroids in all of the 2 to 4 year-old Great Lakes salmon stocks that were examined (Leatherland 1992). Tumors associated with exposure to high levels of PAHs have been detected in brown bullhead in the Great Lakes area (Baumann et al. 1982).

Effects on the immune system have also been documented. At a number of Great Lakes sites, a survey of herring gulls and Caspian terns demonstrated a suppression of T-cell-mediated immunity following prenatal exposure to organochlorine pollutants, particularly

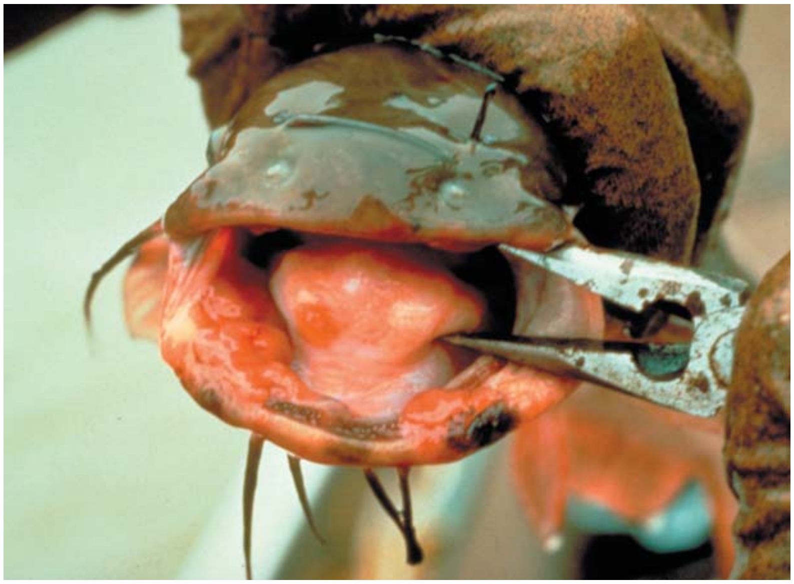
Photo: U.S. EPA Great Lakes National Program Office

PCBs (Grasman et al. 1996). Section 4 provides a more detailed description of the effects of chemicals on wildlife.

8.4.2 Animal Experiments

A number of animal experiments have demonstrated a wide range of health outcomes from exposure to PCBs, mercury and chlorinated dibenzo-p-dioxins (CDD).

PCBs (polychlorinated biphenyls): Animals exposed orally to PCBs developed effects to the hepatic, immunological, neurological, developmental and reproductive systems. Effects have also been reported in the gastrointestinal and hematological systems (ATSDR 1998). Animal ingestion studies strongly support the finding that more highly chlorinated PCBs (i.e., 60% chlorine by weight) are carcinogenic to the livers of rats, while the lower chlorinated PCBs result in a lower incidence of total tumors and more benign tumors (Buchmann et al. 1991; Sargent et al. 1992.)

Mercury: Long-term, high level animal ingestion exposure to mercury has been associated with cardiovascular (Arito and Takahashi 1991), developmental (Fuyuta et al. 1978; Nolen et al. 1972; Inouye et al. 1985), gastrointestinal (Mitsumori et al. 1990), immune (Ilback 1991), renal (Yasutake et al. 1991; Magos et al. 1985; Magos and Butler, 1972; Fowler 1972) and reproductive effects (Burbacher et al. 1988; Mitsumori et al. 1990; Mohamed et al. 1987). The studies also indicate that the nervous system is particularly sensitive to mercury exposure by ingestion (Fuyuta et al. 1978; Magos et al. 1980, 1985). In addition, growth of kidney tumors has been reported in animals administered methylmercury in drinking water or diet for extended periods (Mitsumori et al. 1981, 1990).

CDDs (chlorinated dibenzo-p-dioxins): In specific species (e.g., guinea pig), very low levels of 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) have resulted in the death of the exposed animal after a single ingestion dose (NTP 1982). At non-lethal levels of 2,3,7,8-TCDD by ingestion, other effects reported in animals include weight loss (NTP 1982), biochemical and degenerative changes in the liver (NTP 1982; Kociba et al. 1978), and a decline in blood cells (Kociba et al. 1978). Dermal effects in animals (e.g., hair loss, chloracne) have also been reported by ingestion exposure (McConnell et al. 1978). In many species, the immune system and fetal development are particularly susceptible to 2,3,7,8-TCDD exposure. Offspring of animals receiving oral exposure to 2,3,7,8-TCDD developed birth defects such as skeletal deformities and kidney defects, weakened immune responses, impaired reproductive system development, and learning and behavior impairments (Giavini et al. 1983; Gray and Ostby 1995; Tryphonas 1995; Schantz and Bowman 1989; Schantz et al. 1992). Reproductive effects in the form of miscarriages were reported in rats, rabbits, and monkeys exposed orally to 2,3,7,8-TCDD during pregnancy (McNulty 1984). Rats of both sexes were observed to have endocrine changes in the form of alterations in sex hormone levels with dietary exposure. Other reproductive effects include a decline in sperm production in male rats. Cancer of the liver, thyroid, and other organs in rats and mice exposed orally to 2,3,7,8-TCDD were measured (NTP 1982; Kociba et al. 1978). Research evidence is also increasing supporting the neurotoxic effect for mammals and birds from ingestion exposure to dioxin-like compounds, including certain PCBs and CDFs. Changes in thyroid hormones and neurotransmitters, singly or together, at critical periods in the development of the fetus are considered responsible for the neurological changes (Brouwer et al. 1995; De Vito et al. 1995; Henshel et al. 1995b; Henshel and Martin 1995a; Vo et al. 1993).

8.4.3 Human Health Studies

Demonstrating health effects in humans from chronic, low-level exposure to persistent organic pollutants typically encountered in the Great Lakes region is a challenge for researchers. Exposure to contaminants from Great Lakes fish is dependent upon the amount eaten and species consumed. Overall, there is limited information available on exposure levels, body burdens and health effects for people who consume Lake Erie fish. Currently, the Agency for Toxic Substances and Disease Registry (ATSDR) is funding studies investigating populations that reside in the Lake Erie basin and consume Lake Erie fish. The ATSDR studies will determine exposure and body burden levels, and potential health effects. In addition, two Health Canada fish consumption studies include participants from the Lake Erie basin. Along with results from the Lake Erie studies, research examining other Great Lakes will be used to assess risks and benefits of eating Great Lakes fish.

Exposure Studies

Due to the effects of bioaccumulation and biomagnification, fish consumption has been shown to be a major pathway of human exposure to PBT chemicals such as PCBs (Birmingham et al. 1989; Fitzgerald et al. 1996; Humphrey 1983; Newhook 1988), exceeding exposures from land, air, or water sources (Humphrey 1988). Humphrey (1988) reported that PCBs were the dominant contaminants detected in Lake Michigan trout (3,012 parts per billion or ppb) and chinook and coho salmon (2,285 ppb), surpassing other contaminants such as DDT (1,505 ppb, 1,208 ppb), hexachlorobenzene (5 ppb, 5 ppb), oxychlordane (25 ppb, none shown), trans-nonachlor (195 ppb, 162 ppb), and dieldrin (75 ppb, 53 ppb), respectively in trout and salmon. Fish specimens collected from the dinner plate of study participants were used to determine these median PCB concentrations. Recently, total PCB levels have decreased in most Lake Michigan fish species and appear to remain below the FDA action level of 2000 ppb, but the concentrations in chinook and coho salmon have risen slightly since the late 1980s (Stow et al. 1995).

Early investigations of Lake Michigan fish consumption have broadened our knowledge about transmission of contaminants from fish to humans, including maternal exposure of the fetus and infant. Investigating a cohort of State of Michigan fish eaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of 24 pounds/year or 11 kg/year) had median serum PCB levels approximately four times higher (56 ppb) than those who consumed no Great Lakes fish (15 ppb). PCBs have also been detected in adipose tissue (Stellman et al. 1998), breast milk (Jacobson et al. 1984), and cord blood (Fein et al. 1984) and associated with consumption of contaminated fish (ATSDR 1998). Schwartz et al. (1983) demonstrated that consumption of Lake Michigan fish was positively associated with the PCB concentration in maternal serum and breast milk. Maternal serum PCB concentrations were also positively associated with the PCB levels in the umbilical cord serum of the infant (Jacobson et al. 1983).

Although the levels of PCBs have declined in most species of Lake Michigan fish, lipophilic pollutants, such as PCBs, have a tendency to bioaccumulate in the human body. Hovinga et al. (1992) reported a mean serum PCB concentration of 20.5 ppb in 1982 for persons consuming >24 pounds of Lake Michigan sport fish per year, and 19 ppb in 1989, demonstrating little decline within the 7 year interval. For those ingesting <6 pounds of Lake Michigan sport fish per year, the mean serum PCB concentrations were 6.6 ppb in 1982, and 6.8 ppb in 1989. The mean serum PCB concentrations for those consuming <6 pounds of Lake Michigan fish per year are comparable to the mean serum PCB levels of 4 to 8 ppb found in the general population who do not have occupational PCB exposure (Kreiss 1985).

Research has shown that at risk communities for exposure to contaminants from fish consumption include Native Americans, minorities, sport anglers, the elderly, pregnant women, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Dellinger et al. 1996, Fitzgerald et al. 1996, Lonky et al. 1996, Schantz et al. 1996). These communities may consume more fish than the general populations or have physiologic attributes, such as physical and genetic susceptibilities, that may cause them to be a greater risk. Higher body burdens of mean serum PCBs and DDE were found in an older cohort of Lake Michigan fish eaters (i.e., 50 years of age) who were compared to non-fish eaters (Schantz et al. 1996). Fish eaters had mean serum PCB levels of 16 ppb while the non-fish eaters had mean levels of 6 ppb. For DDE, fish eaters had mean serum levels of 16 ppb and the non-fish eaters had a mean level of 7 ppb.

Gender difference in fish consumption is an issue of interest that is being investigated, toward better identifying at-risk populations. One Michigan sport anglers study, with subjects between the ages of 18-34 years, demonstrated gender differences with males tending to consume more fish than female subjects (Courval et al. 1996). Conversely, Health Canada's Great Lakes Fish Eaters Study (discussed below) found that women in the high fish consumption group eat more fish than men (Kearney 2000, personal communication).

In a recent Health Canada study carried out in five areas of concern in the lower Canadian Great Lakes, 4,637 shoreline fishers were interviewed. The demographic data show that there is no such thing as a *typical* fisher. People who like to fish come from different cultural backgrounds, are different ages and have different occupations. Thirty-eight percent of the shoreline fishers interviewed reported eating at least one meal of fish during the previous 12 months. Twenty-seven percent of shoreline fishers interviewed reported eating more than 26 meals of fish in a year. As the number of fish meals consumed increased, so did the likelihood that parts of the fish other than the fillet were being consumed. Approximately one third of the fish eaters said that they used the *Guide to Eating Ontario Sport Fish* (Health Canada, 2000).

A concurrent project, the Great Lakes Fish Eaters Study (not yet released) took a more in-depth look at exposure to environmental contaminants in people eating large amounts of Great Lakes fish. Environmental contaminant levels were measured in blood samples collected from the study participants. As well, nutritional and social benefits associated with consumption of Great Lakes fish were examined (Kearney, 2000, personal communication).

In a study by Kearney et al. done in 1992-93, blood levels of PCBs in men and women between Great Lakes fish eaters and non-fish eaters were compared for Mississauga and Cornwall (in the Lake Ontario basin). For male fish eaters the median level was 5.5 ppb, for male non-fish eaters it was 3.9 ppb. For women fish eaters and non-fish eaters the median levels were 3.4 and 3.2 ppb, respectively. These differences were statistically significant for men only. Relative to fish eaters and families on the north shore of the St. Lawrence River (geometric mean 35.2 ppb) and Quebec Inuit (geometric mean 16.1 ppb), these values are low. Total mercury levels measured in the same participants were also low; the median levels for male Great Lakes fish eaters and non-eaters were 2.65 and 1.70 ppb, respectively. Median levels for female Great Lakes fish eaters and non-eaters were 2.10 and 1.45 ppb, respectively. Levels were generally at the lower end of the *normal acceptable range* (< 20 ppb) as defined by the Medical Services Branch of Health Canada and based on WHO guidelines.

Hanrahan et al. (1999) corroborated previous findings relating frequent Great Lakes sport fish consumption to a higher body burden for PCBs and DDE. The study examined relationships between demographic characteristics, Great Lakes sport fish consumption, PCB, and DDE body burdens. The blood serum PCB and DDE levels in a large cohort (538) of sport fish consumers for Lakes Michigan, Huron and Erie were significantly higher than in reference groups. Body burdens varied by exposure group, gender, and Great Lake. Years of consuming Great Lakes fish were the most important predictor of PCB levels, while age was the best predictor of DDE levels.

Falk et al. (1999) examined fish consumption habits and demographics in relation to serum levels of dioxin, furan, and coplanar PCB congeners in one hundred subjects. Body burdens varied by gender and lake (Michigan, Huron, and Erie). Between-lake differences were consistent with fish monitoring data. Consumption of lake trout and salmon was a significant predictor of coplanar PCBs. Consumption of lake trout was also a significant predictor of total furan levels. Fish consumption was not significantly correlated with total dioxin levels.

Health Effects

A health effect associated with a particular exposure to a chemical contaminant does not in itself establish causality. The association becomes of interest when a number of different researchers produce similar findings. A small number of study participants, presence of multiple chemical exposures, and exposure data that lack a certain degree of precision often limit occupational and environmental epidemiologic studies examining human health effects from chemical contaminants. When epidemiological studies are judged against factors, among which are consistency of findings, dose-response effect, biological plausibility, and strength of association (i.e. greater risk in the exposed vs. non-exposed), the association between observed exposure and a subsequent adverse health effect, though not establishing causality, is made stronger.

Developmental, reproductive, neurobehavioral or neurodevelopmental, and immunological effects of exposure to lipophilic pollutants (i.e. organochlorines) have been examined in studies conducted within the Great Lakes basin and outside the basin. The following are selected studies that have reported an association between exposure through sport fish consumption and these outcomes.

Developmental effects in the form of a decrease in gestational age and low birth weight have been observed in a Lake Michigan Maternal Infant Cohort exposed prenatally to PCBs (Fein et al. 1984). These findings have also been observed in offspring of women exposed to PCBs occupationally in the manufacture of capacitors in New York (Taylor et al. 1989).

Reproductive effects have also been reported. Courval et al. (1997 and 1999) examined couples and found a modest association in males between sport-caught fish consumption and the risk of conception failure after trying for at least 12 months. Exposure to PCBs in fish was also associated with a rise in the risk of infertility (Buck et al. 2000). Studies of New York state anglers have not shown a risk of spontaneous fetal death due to consumption of fish contaminated with PCBs (Mendola et al. 1995), or an effect to time-to-pregnancy among women in this cohort (Buck et al. 1997).

Neurobehavioral or neurodevelopmental effects have been reported for exposure to PBT chemicals in newborns, infants, and children of mothers consuming Great Lakes fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed newborn infants of mothers consuming >6.5 kg/year of Lake Michigan fish had neurobehavioral deficits of depressed reflexes and responsiveness, when compared to non-exposed controls (Jacobson et al. 1984). The fish-eating mothers consumed an average of 6.7 kg of Lake Michigan contaminated fish per year equal to 0.6 kg or 2 to 3 salmon or lake trout meals/month. Prior to study admission, exposed mothers were required to have fish consumption that totaled more than 11.8 kg over a 6-year period. Subsequent studies of the Michigan Cohort have revealed neurodevelopmental deficits in short-term memory at 7 months (Jacobson et al. 1985) and at 4 years of age (Jacobson et al. 1990b), and also growth deficits at 4 years associated with prenatal exposure to PCBs (Jacobson et al. 1990a). A more recent investigation of Jacobson's Michigan Cohort revealed that children most highly exposed prenatally to PCBs showed IQ deficits in later childhood (11 years of age) (Jacobson and Jacobson 1996).

Highly exposed children received prenatal and postnatal PCB exposure equal to at least 1.25 ppm in maternal milk, 4.7 ppb in cord serum, or 9.7 ppb in maternal serum. The authors attributed these intellectual impairments to in-utero exposure to PCBs.

The Oswego Newborn and Infant Development Project examined the behavioral effects in newborns of mothers who consumed Lake Ontario fish that were contaminated with a variety of PBT chemicals. These infants were examined shortly after birth (12-24 and 25-48 hours). Lonky et al. (1996) found that women who had consumed >40 PCB equivalent pounds of fish in their lifetime had infants who scored more poorly in a behavioral test (Neonatal Behavioral Assessment Scale) than those in the low-exposure (<40 PCB equivalent pounds of fish) or control group. In a follow-up study Stewart et al. (1999), concluded that the most heavily chlorinated and persistent PCB homologues were elevated in the umbilical cord blood of infants whose mothers ate Great Lakes' fish. The concentration was significantly dependent on how recently the fish were consumed relative to pregnancy. A further study attempting to relate the level of PCBs to scores in infants is underway.

Mergler and coworkers (1997) reported early nervous dysfunction in adults who consumed St. Lawrence River fish. However, in initial testing, neurotoxic effects were not observed by Schantz and coworkers (1999) in an older adult population (i.e. >50 years) of Lake Michigan fish-eaters with exposure to PCB and DDE. This study is ongoing. Immunological effects have also been reported. Smith's study (1984) demonstrated that maternal serum PCB levels during pregnancy were positively associated with the type of infectious diseases that infants developed during the four months after birth. In addition, incidence of infections has been shown to be associated with the highest fish consumption rate for mothers - i.e., at least three times per month for three years (Swain 1991; Tryphonas 1995).

Other health effects have been documented with PCB exposure. Elevated serum PCB levels were associated with self-reported diabetes and liver disease in cohorts of Red Cliff and Ojibwa Native Americans (Dellinger et al. 1997, Tarvis et al. 1997). Fischbein and coworkers (1979) found that workers exposed to a variety of PCB aroclors reported joint pain.

The nervous system is particularly sensitive to the effects of methylmercury exposure including tingling sensation in the extremities, unsteady gait, memory loss, paraplegia, hallucination, loss of consciousness and death (Tsubaki and Takashi 1986; Al-Mufti et al. 1976). Developmental effects have also been observed in infants born to mothers exposed to methylmercury, including brain damage, mental retardation and retention of primitive reflexes (Cox et al, 1989).

A summary of health effects studies inside and outside the Great Lakes basin can be found in the paper published by Johnson and coworkers (1998). The U.S. Agency for Toxic Substances and Diseases Registry (ATSDR) has published toxicological profiles for hazardous substances, including PCBs and mercury. The full reports can be obtained from ATSDR, and information is available at www.atsdr.cdc.gov/toxpro2.html. Health Canada has also published documents about fish consumption and health effects (www.hc-sc.gc.ca/english/protection/warnings.html.)

8.5 Exposure and Health Effects Research Needs for PBT Chemicals

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in the environment and in animal and human tissues. Within the ecosystem, there are encouraging signs and successes. For example, contaminant declines have been observed at most Great Lakes sites sampled for contaminants in herring gull eggs (Environment Canada and U.S. EPA 1999).

Reductions of PBT chemicals in human tissues include lead in blood, and organochlorine contaminants in breast milk. This translates into a reduced risk to health for these contaminants. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Human health research has identified fish consumption as the major pathway of exposure to contaminants from Lake Erie and other Great Lakes. Body burdens from consumption of contaminated fish have been noted in highly exposed populations and human health effects have subsequently been reported. Despite these findings, issues related to environmental exposures and human health still remain. This supports the need for continued reductions of PBT chemicals in the Lake Erie basin. Health research needs to continue, but a shift in priorities is now needed to prevention and intervention strategies. Efforts on public health advisories to protect health from current environmental exposures, and public outreach related to risks and benefits of fish consumption, need to continue where appropriate.

Photo: Upper Thames River Conservation Authority

Additional research is needed in the following areas:

1. Continue to assess the role of PBT chemicals on neurobehavioural and neurodevelopmental effects.
2. Improve the assessments of chemical mixtures.
3. Assess the role that endocrine disruption may play in human health effects, such as reproductive health.
4. Research on PCB Congeners.
5. Research Biologic Markers.

8.6 Conclusion

For persistent bioaccumulative toxic chemicals, the current weight of evidence regarding human health effects is supportive of the need for continued reductions in the levels of PBT chemicals in the environment. While public health advisories and other guidelines can be followed to protect human health from current environmental exposures, continued reductions in the level of persistent pollutants in the environment, both globally and regionally, are ultimately the most effective long-term solution to minimizing the health risks to Lake Erie basin population.

Although progress has been made in defining the health threat from Great Lakes pollutants (including Lake Erie pollutants), important issues remain requiring our diligent efforts. To protect human health in the Lake Erie basin, actions must continue to be implemented on a number of levels. The GLWQA calls for ". . . develop[ing] approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health" (IJC 1987). For the public health arena, there are a number of issues that will help to identify these long-term, low-level health effects. Research in these areas will provide a more comprehensive view of the threat to human health from environmental contaminants, and enable public health agencies to utilize this knowledge to protect the public health more effectively. A shift in priorities is now needed to prevention, intervention, and collaborative activities, including the work of LaMPs. In particular, contaminant levels monitoring in environmental media and in human tissues is an activity in particular need of support, to better quantify the extent of exposure. Health risk communication is also a crucial component to protecting and promoting human health in the basin. The LaMP can play a key role in informing people about human health impacts of environmental contaminants and what they can do to minimize their health risks. This includes linking people to information that is packaged in a variety of ways and targeted to a range of audiences, to enable people to make informed choices about their health.

Drinking Water

Over time, public water systems have been found to supply drinking water of good quality. Monitoring and corrective measures to reduce and eliminate levels of contaminants in treated water are essential components in continuing to assure the safety of drinking water supplies. As the population grows, and as more people rely on the drinking water supply from the lakes, these control measures must be adequate to reduce the risk from exposure to microbes in Great Lakes waters (Health Canada 1997). Ultimately, however, source water protection (protection of the raw waters) is the key to maintaining the good quality of drinking water supplies. The Lake Erie LaMP has designated drinking water from Lake Erie to be unimpaired but an area to protect (see Section 4).

Recreational Use

Pollution controls and remediation, such as reducing combined sewer overflows and improvements in sewage treatment, have continued to improve water quality in many areas of the Great Lakes basin in recent years. Long term planning for remediation of microbial contaminants in recreational water needs to include identification of sources of contamination, determination of which sources can be remediated and the costs involved, and timelines for implementation (Health Canada 1998a; Lake Erie LaMP 1999; U.S. EPA 1998a). Although it may not be feasible to eliminate microbial level exceedences completely in recreational waters, it is expected that as sources continue to be remediated, exceedences will continue to decline (Lake Erie LaMP 1999; U.S. EPA 1998a). The Lake Erie LaMP has designated recreational use as impaired (see Section 4).

Fish Consumption

Diet contributes over 95% of the PBT chemical intake for the general population, with drinking water, recreational water, and air constituting very minor exposure routes. Consequently, the approach by various public health agencies has been to focus on groups at higher risk of exposure to PBT chemicals from Great Lakes sources, such as high consumers of sport fish. Due to the presence of PCBs, organochlorine pesticides, mercury, and other chemicals in fish from the Lake Erie basin, fish advisories are issued that recommend restrictions on fish consumption. Tighter restrictions are recommended for pregnant women, women of childbearing age and children. When communicating health risk information to fish consumers, it is important to recognize that fish are a good source of low-fat protein. Most of the fish harvested from Lake Erie by sport and commercial fishermen meet current objectives for contaminants, and those fisheries have social, cultural and economic benefits. The Lake Erie LaMP has designated fish consumption as impaired (see Section 4).

Proposed and ongoing actions to further public health intervention and research are presented in Table 8.3

Photo: Jeff Brick

Table 8.3: Human Health Action/Implementation Plan Matrix

Description	Project Lead	Status
Drinking Water		
Assess sources of drinking water. By 2003, conduct source water assessment using U.S.EPA Source Water Protection Protocol to delineate source areas and assess significant potential sources of contamination in order to protect water supplies.	U.S. states, U.S. EPA and local communities	See: U.S. EPA website: www.epa.gov/safewater/protect/swap.html
In Canada (Ontario), assessment of drinking water supply sources is done by the Ontario Drinking Water Surveillance Program and reported to the public.	Ontario MOE	Ongoing see Ontario MOE website: www.ene.gov.on.ca
Protect drinking water sources. This would include specific actions such as: wellhead protection plans and source water protection plans for water supply on Lake Erie	U.S. states, U.S. EPA and and local communities; Ontario MOE	Ongoing: US see: www.epa.gov/safewater/protect Canada see: www.ene.gov.on.ca
Raise awareness and publicize the availability of drinking water monitoring information to the general population. Confidence Reports in the U.S. and Ontario Drinking Water Surveillance Program in Canada.	State/Provincial and Federal Health and Environmental Agencies and local governmental agencies	Ongong see: U.S.: www.epa.gov/safewater Canada: www.ene.gov.on.ca
Promote epidemiological research (exposure and health effects) on drinking water borne diseases in the Great Lakes and for the Lake Erie basin in particular. This should include an evaluation on public vs. private sources.	Funded research from NIEHS, U.S. EPA, Health Canada, academic researchers	
Continue to research the implications of aluminum and chlorination disinfection by-products on human health and promote the development of guidelines for water treatment to minimize any risk to health that may exist.	U.S. EPA, Health Canada/Ontario	
Improve the identification/diagnosis and promote the reporting of water borne disease incidences to help in response to disease outbreaks, improving information for epidemiological studies and for tracking trends over time (indicator).	U.S. CDC, State and Local Health Departments; Province of Ontario and Local Health Units	
Research and development of technologies and methods for the detection and treatment of *Giardia*, *Cryptosporidium* and other parasites in drinking water to protect human health.	U.S. Federal and State health agencies, U.S. EPA; Health Canada	
Promote ambient monitoring of Lake Erie drinking water intakes, and tributaries that can potentially degrade water quality at these intakes, and storage of data in electronic databases. Microbiological and turbidity monitoring should be included in the monitoring program.	IJC Indicator Implementation Task Force; U.S. EPA OGWDW; EPA GLNPO; Great Lakes Commission	In Canada this is done and reported see www.ene.gov.on.ca. U.S. may be done but not required to be reported.

Description	Project Lead	Status
Recreational Water		
Continue to promote and expand the U.S. BEACH surveillance program and corollary programs for the Canadian shoreline. This would include outreach to local governments along the Lake Erie shoreline for their involvement.	U.S. EPA, Health Canada with State/Provincial and local governments	Ongoing. U.S. see: www.epa.gov/OST/beaches/ In 2002 Ohio: of 52 beaches 85% met WQ objectives 95% of the time. PA: all 13 beaches met WQ objectives 95% of the time. NY: of 17 beaches 70% met WQ objectives 95% of the time. For Canada see: www.ene.gov.on.ca
U.S.EPA's goal under the Great Lakes Strategy is that by April 2004 all states will have adopted criteria as protective as U.S.EPA's 1986 Ambient Water Quality Criteria for Bacteria in coastal waters.	U.S. EPA and States	Ohio and Pennsylvania: complete NY: under discussion with U.S. EPA due to disagreement on the monitoring surrogate.
Continue the development of rapid sampling technologies and techniques for microbial and viral contamination and promote the dissemination and use of the instrument and sampling methods to local governments along the Lake Erie shoreline.	U.S. EPA BEACH program, Health Canada, Ontario, State and local governments	U.S. see: www.epa.gov/OST/beaches/ Canada see: www.ene.gov.on.ca
Promote epidemiological research on recreational water borne diseases in the Great Lakes and for the Lake Erie basin in particular. This should also include research on the health implications of interstitial bathing waters, CSO/SSO discharges and inhalation of water spray.	Funded research from NIEHS, U.S. EPA, Health Canada and academic researchers	NEEAR Study: During summer 2003, U.S.EPA began a multi-year study to investigate the link between water quality indicators of microbial contamination, swimming at coastal beaches, and subsequent swimmer illness. The aims of the study are to begin the next generation of rapid and cost-effective water-quality testing methods, new national recommendations for fecal contamination indicators, and guidelines for monitoring recreational water quality. New water quality indicators will be tested to see if they more accurately determine illnesses in swimmers.See www.epa.gov nerlcwww/neearnerl.htm

Description	Project Lead	Status
Fish Consumption		
Research the health benefits of fish consumption to better quantify those benefits for use in risk assessment for developing fish consumption advice.	USEPA/OST	
Develop a meaningful Lake Erie indicator for fish consumption. Promote the reporting of contaminant levels in edible portions of fish collected by State Agencies responsible for fish consumption advisories.	Lake Erie LaMP partners, SOLEC, State/Provincial Agencies	Development of fish consumption indicator ongoing. Reporting of contaminant levels in sport-fish ongoing.
Increase awareness, use and effectiveness of fish advisories in the Lake Erie populations targeting sensitive populations (minorities, women of childbearing age, immigrants, the elderly and etc.)	State and Province Government Agencies, U.S. EPA, Health Canada, local governments	
U.S. EPA grant to Delta Institute on behalf of the Lake Erie Forum for Outreach of Fish Consumption Advisories to Minority and At Risk Populations - This is a pilot grant to develop and promote the outreach of fish consumption advice to minority and at risk populations in the Lake Erie Basin. The grant emphasizes the development and promotion of culturally sensitive and effective outreach materials.	U.S. EPA	COMPLETE: Outreach of Fish Consumption Advisories to Minority and At Risk Populations. Materials available through the Lake Erie LaMP Public Forum.
ATSDR grant to Consortium for the Health Assessment of Great Lakes Fish Consumption - This is an ongoing project to conduct a Great Lakes basin wide outreach program to distribute sport-fish advisory materials to women of childbearing age and to host a conference to establish a forum for exchange of information on successful distribution of the sport fishing advisory to women of childbearing age and other high risk populations. The Consortium of Great Lakes states developed outreach materials for women of childbearing age and minority groups which are being utilized by seven of the eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin). These outreach materials such as posters and recipe cards are being adapted by each of the states for their specific needs, and are being distributed at women and children's clinics, health fairs, state fairs, and fishing shows to increase health advisory awareness.	ATSDR/State of Wisconsin	

Description	Project Lead	Status
Exposure and Health Effects Research		
Promote exposure, outcome and epidemiological research for PBT chemicals in the Great Lakes and specifically within the Lake Erie basin. This research should include the five needs for the future listed in Section 8.5.	ATSDR, NIEHS, U.S. EPA, Health Canada, Environment Canada, State, Provincial and local Health Departments	
Shoreline Survey - In a recent Health Canada study carried out in five Areas of Concern in the lower Canadian Great Lakes (Dawson, 2000), 4,637 shoreline fishers were interviewed. The demographic data show that there is no such thing as a "typical" fisher. People who like to fish come from different cultural backgrounds, are different ages and have different occupations. A report of the results is expected to be available by mid-year 2000.	Health Canada	
Great Lakes Fish Eater Study - A concurrent project, the Great Lakes Fish Eaters Study (not yet released) has taken a more in-depth look at exposure to environmental contaminants in people eating large amounts of Great Lakes fish. Environmental contaminant levels were measured in blood samples collected from the study participants. As well, nutritional and social benefits associated with consumption of Great Lakes fish were examined.	Health Canada	
Other		
Development of a Human Health Resource Home Page for the Great Lakes with pages specifically oriented towards human health issues in the Lake Erie basin	U.S. EPA, Health Canada, ATSDR, States, Provinces, LaMP partners	www.epa.gov/safewater/security/flyers index.html www.great-lakes.net/lists/beachnet beachnet.info www.glc.org/announce/03 07beachcast www.epa.gov/waterscience/beaches/
Assessment of social dimensions of health in the Lake Erie basin. Identify references available, and the need to address the social dimensions of health, further to the WHO definition of health	LaMP Public Forum, Health Canada, U.S. EPA	

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